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Project Summary

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Pilot-Scale Anaerobic Filter Treatment of Heat Treatment Liquor

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Using the anaerobic filter to treat liquor waste resulting from heat treatment of raw sludge in municipal sewage treatment plants was demonstrated. The liquor, which contains high concentrations of soluble wastes, is often returned to the head end of a plant where it can impose an additional load on the plant's operation and reduce its efficiency.

Operational data from a laboratory and two pilot anaerobic filter columns, operated over an 18-month period, demonstrated high levels of BOD and COD removals from the raw heat treatment liquor (HTL). The generated gas contained 65% to 70% methane.

Based on the pilot column studies, a suggested design and costs for an anaerobic filter unit were developed. These costs were compared with costs of other means of treatment such as the aerobic alternative. The anaerobic filter process had lower capital and operating costs than other modes of treatment. The gas produced would be sufficient to maintain the temperature of the filter at 35° C and provide additional fuel for other plant uses. These calculations show a net profit in operating costs. Further investigations to optimize design configurations are suggested.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

A pilot plant study was conducted on the anaerobic filter treatment of HTL from the heat treatment of sludge from a municipal sewage plant.

The anaerobic filter's capability of removing large amounts of soluble organic matter with no oxygen required, at relatively low hydraulic detention times and low solids production, can result in distinct advantages for the pretreatment of high strength organic wastes.

Although the concept of the anaerobic filter has been studied for 15 or more years, most of the work has been on laboratory scale systems, with little pilot or full-scale information developed. The potential cost benefits of this process, however, have increased because of its low energy requirement when compared with aerobic systems typically applied to soluble organic wastes. Consequently, operation on a pilot scale to verify kinetic data, develop practical operating and control schemes, and uncover scale-up problems was clearly appropriate.

Heat Treatment Liquor (HTL)

Heat treatment of municipal primary and secondary sludge is practiced at over 100 plants. The liquor from dewatering the treated sludge contains a high concentration of organics solubilized

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in the process. This load can contribute up to 30% of the raw waste load of the plant and requires either pretreatment or significant additional capacity in the treatment plant.

The anaerobic filter was proposed as a cost effective way to pretreat this waste. To develop design parameters and provide data for a cost comparison with alternative aerobic treatment, an anaerobic filter laboratory and full-scale pilot plants were operated on a typical municipal HTL from a sewage treatment plant. The characteristics of HTL are shown in Table 1.

Pilot Plant Studies

The laboratory column was 5 cm in diameter and contained 1.25 m of 1.6-cm plastic Pall Rings media, porosity 85%. The two full-scale pilot columns were each 60 cm square by 3.5 m high and contained 1.85 m of 9-cm plastic Pall Rings, porosity 95%. Temperature was maintained at about 35° C for these studies.

Table 1. Characteristics of HTL from a Sewage Treatment Plant

Constituent	Range	Average
pH	4.9-5.8	5.2
Alkalinity, mg/L	600-1560	1075
Total Solids, mg/L	7390-8460	7735
Volatile Solids, %	55-83	71
COD, mg/L	10160-11540	10750
BOD, mg/L	3830-6100	4965
TKN, mg/L	840-990	920
NH_3-N, mg/L	270-390	295
Volatile Acids, mg/L	1970-2230	2085

Loading Conditions

Column 1 was operated at a constant load throughout the study; the loadings to column 2 and the laboratory column were increased in several increments during the study. Tables 2 and 3 present summarized operational data, collected after an initial acclimation period, for the pilot units. Figure 1 illustrates the removal of BOD and COD with time for the pilot units.

The primary gases produced in anaerobic treatment are carbon dioxide and methane. During the study, the methane and carbon dioxide contents of the gas samples were measured, versus soluble COD removed (COD_R). The following relationships were developed.

m^3 Total Gas Produced = 0.50/kg COD_R 100%

m^3 Methane Produced = 0.34/kg COD_R 68%

m^3 CO_2 Produced = 0.15/kg COD_R 29%

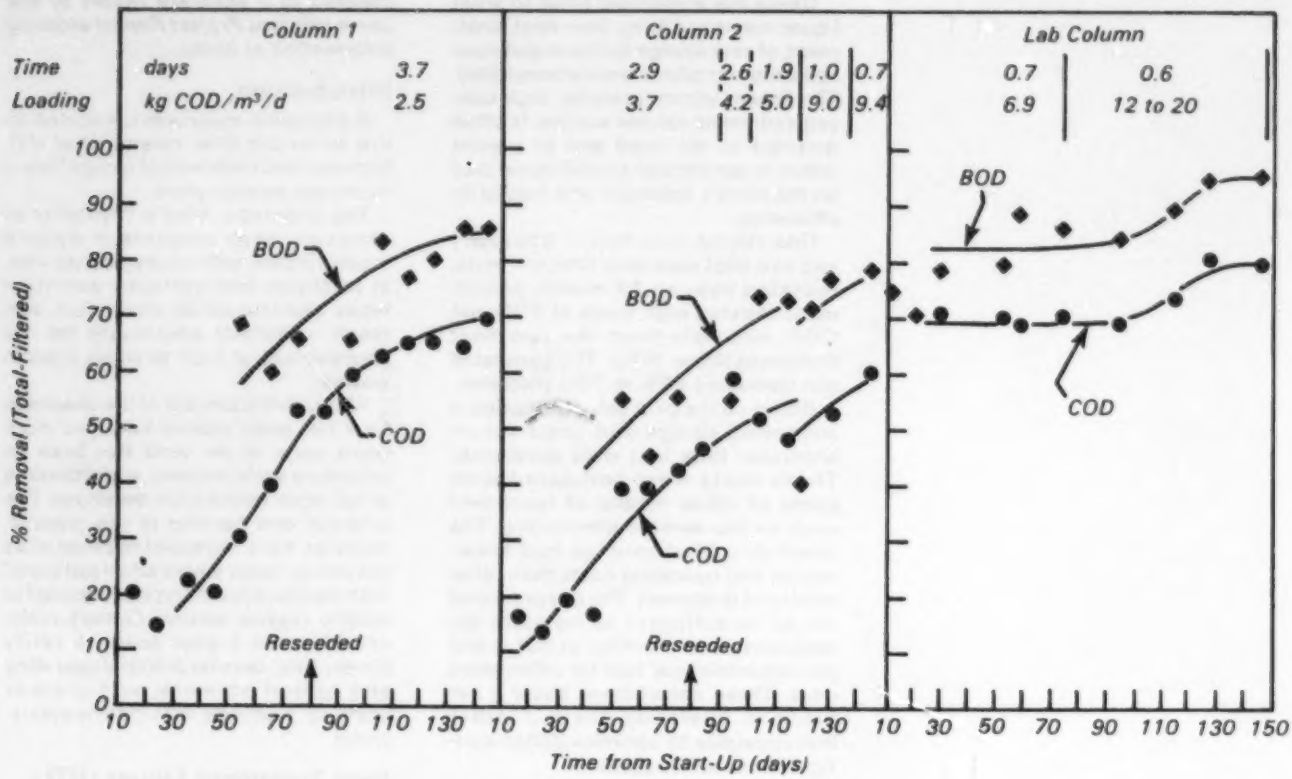

Figure 1. BOD and COD removal from anaerobic filter study of HTL at 35°C.

The average value of 0.5 m^3 gas/kg soluble COD removed is consistent with typical gas production and with COD correlations found in the literature and in previous studies.

Summarizing the results, column 1 at 3.7 days detention achieved 80% to 85% BOD removal and 65% to 70% COD removal; column 2 at 1 day detention achieved 65% to 75% BOD removal and 55% to 60% COD removal; and the laboratory column at 0.6 day detention achieved 80% to 95% BOD removal and 70% to 90% COD removal. The COD removals reflect the nonbiodegradable COD fraction, which was in the range of 10% to 20% of the HTL COD.

Loading Removal Relationships

For volumetric loading rates from 5 to 25 kg/COD/m^3/d, the laboratory filter consistently removed from 60% to 80% of the COD. The pilot plant filters, operated at 1 to 11 kg/COD/m^3/d, exhibited lower removals and a decline in removal with increased loading. This decrease, however, was attributed to the slow buildup of the anaerobic microorganisms on the larger media and their poorer retention on the large media at higher flow rates.

At the conclusion of the studies, the filter media was removed and a determination of the solids, both attached and suspended, was made. A high percentage of the solids in column 1 were suspended in the bottom 60 cm. Column 2 had a fairly uniform distribution of both attached and suspended solids throughout the column. Over 90% of the solids were attached in column 2 and the laboratory column. The laboratory

Table 2. Summary of Operational Data for Laboratory Anaerobic Filter

Date Day, No.	Flow, L/d	Deten. Time, days	Loading Rate, kg COD/m^3/d	Gas Prod., L/d	Gas,* m^3/kg COD_R	COD* Removed, %	BOD* Removed, %
29-33	2.7	0.8	6.7	5.31	0.53	71	85
49-55	3.4	0.6	7.1	6.43	0.61	70	92
57-60	3.0	0.7	6.3	4.10	0.46	68	92
71-75	2.9	0.7	11.6	6.92	0.40	70	87
92-96	3.6	0.6	12.3	10.28	0.58	68	88
113-120	3.5	0.6	14.4	16.70	0.75	74	93
120-131	4.3	0.5	20.1	19.60	0.57	81	95
141-147	3.7	0.6	14.0	12.80	0.55	79	96

*Based on influent total and effluent filtered; COD_R is COD removed.

Table 3. Summary of Operational Data for Anaerobic Filters, Column 1 and Column 2

Date Day, No.	Flow, L/d	Deten. Time, days	Loading Rate, kg COD/m^3/d	Gas Prod., m^3/d	Gas,* m^3/kg COD_R	COD* Removed, %	BOD* Removed, %
			Column 1				
42-51	174	3.90	2.59	0.179	0.48	21	
52-61	165	4.12	2.23	0.312	0.62	33	
62-71	107	6.36	1.56	0.252	0.48	49	60
72-81	124	5.48	1.84	+		53	66
82-91	184	3.70	3.07	0.527	0.49	52	
92-102	179	3.80	2.76	0.543	0.49	59	67
103-112	178	3.82	2.37	0.337	0.33	63	83
113-122	180	3.78	2.68	0.613	0.52	65	77
123-133	190	3.58	2.58	0.568	0.49	66	80
134-143	203	3.35	2.13	0.382	0.41	64	86
144-148	180	3.78	1.69	0.175	0.22	68	85
			Column 2				
42-51	350	1.94	5.21	0.187	0.31	17	—
52-61	284	2.39	3.85	0.241	0.24	39	—
62-71	210	3.24	3.06	0.402	0.51	38	45
72-81	170	4.00	2.53	0.314	0.42	43	57
82-91	268	2.54	4.47	0.592	0.41	47	—
92-102	263	2.59	4.06	0.729	0.46	58	56
103-112	245	2.78	3.25	0.451	0.39	52	74
113-122	272	2.50	4.05	0.735	0.57	47	74
125-139	717	0.95	8.75	1.230	0.40	52	66
140-148	988	0.69	9.39	1.360	0.39	55	78

*Based on influent total and effluent filtered; COD_R is COD removed.
+Meter not operating.

column had significantly more attached growth in the bottom section of the filter. On an average mass per unit volume basis, the laboratory column had about 3 to 3.5 times as much attached growth as did either of the two pilot columns.

For purposes of developing a removal rate as a function of the mass of solids retained in the filter (a first order kinetic relationship), it was assumed that the filters acted as completely mixed reactors. Removal rates were based on the solids measured and removals being achieved at the very end of the study.

Column 1 removal rate was quite low; however, the laboratory column and column 2 data showed fair agreement. The reaction rate constant of 0.004 (kg COD removed/d)/(kg column solids)/(mg degradable COD/d)—0.00056 on kg column volatile solids basis—was similar to that found by Mueller and Mancini* in their evaluation of plug flow anaerobic filter data. The low rate in column 1 indicated a high concentration of inert solids in the lower part of the column. These inert solids were evidently "washed out" of the laboratory column and pilot plant column 2 by the higher volumetric flow rates used in these columns.

Anaerobic Filter Design

Differences in the development and retention of methane forming organisms is the apparent factor responsible for the differences in removals seen between the laboratory unit and the pilot columns. The greater solids concentration retained by the small media in the laboratory column resulted in the greater removals per unit of volume. The practical consideration of media cost and solids plugging tend to favor the use of the larger media for a full-scale plant, accepting somewhat lower removals and lower volumetric loadings than with the smaller lab-type media.

Based on the overall results of these studies, and based on a HTL waste COD concentration of 10,000 mg/L, a volumetric loading of 6.5 kg COD/m^3/d was selected. This loading would result in 1.5 days detention. Assuming a total solids concentration in the anaerobic filter of 10 kg/m^3, the loading on a solids basis would be 0.65 kg COD/kg solids/d.

*J.A. Mueller and J.L. Mancini, "Anaerobic Filter Kinetics and Application," Proceedings of the 30th Industrial Waste Conference, May 6-8, 1975, Purdue Univ., Lafayette, Indiana.

Removals in the range of 55% to 65% COD and 75% to 85% BOD were projected for a full-scale installation. Elements included in the anaerobic filter include the digester, filter media, liquor heating and cooling system, pump station, and gas collection and burning equipment. The heat treatment liquor at about 60° C would require cooling in summer; under severe winter conditions, auxiliary fuel may be required to maintain 35° C in the filter.

Cost Comparison

In a preliminary cost evaluation, the cost of the anaerobic filter system is compared with the incremental cost to increase the treatment plant's aeration system and with a separate aerobic system for the HTL. Table 4 presents the preliminary cost estimates. The incremental cost of an aerobic treatment plant was developed based on capacity designed into a 15 MGD plant. Costs are for the additional basin and aeration, capacity in the heat treatment reactor, sludge holding tank, and vacuum filter required to handle the additional sludge load of about 640 kg per day. Operation and maintenance costs include costs for power, maintenance, labor, and sludge handling.

Summary

Pilot plant and laboratory studies show that significant removal of soluble organics from a high strength sludge HTL can be achieved at hydraulic retention times of 0.5 to 2 days. The results of using a laboratory filter containing small media capable of retaining a much higher solids concentration of attached growth were compared with a full-scale pilot plant utilizing typical larger media.

The identification of a possibly more suitable cost effective media to result in maximizing solids retention is an area that requires further study. The economics for anaerobic treatment of sludge HTL compare quite favorably with those for aerobic treatment.

Applying the anaerobic filter to other high strength soluble organic wastes continues to appear promising in light of these pilot plant results, as well as other anaerobic filter studies. A preliminary evaluation of potential economic benefits, and treatability studies with laboratory and pilot scale units, would be recommended for sizing an anerobic filter system for a particular application.

The full report was submitted in fulfillment of Contract No. 68-03-2484 by Hydroscience, Inc., under the sponsorship of the U.S. Environmental Protection Agency.

Table 4. Estimated Costs (1978) for Anaerobic Filter Treatment of HTL Compared with Those for Aerobic Filter Treatment (340 m^3/d; 10,000 mg/L COD)

Filter Type	Capital Cost	Operating Cost
Anaerobic Filter		
No Credit for Methane	*$ 470,000*	*$ 18,400*
Credit for Methane	*$ 470,000*	*$-17,000*
Aerobic Filter		
Incremental Plant Cost	*$ 541,000*	*$ 53,200*
Separate Pretreatment	*$1,036,000*	*$ 68,000*

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***B. Vincent Salotto** is the EPA Project Officer (see below).*
The complete report, entitled "Pilot-Scale Anaerobic Filter Treatment of Heat Treatment Liquor," (Order No. PB 81-218 323; Cost: $11.00, subject to change) will be available only from:

National Technical Information Service
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